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<p>The general goals of AFOSR 85-0048 were to provide a better understanding of observed neutral and plasma structures in the upper atmosphere, and to define appropriate parameterizations for the neutral-plasma interactions governing these structures in comprehensive numerical models of the thermosphere and ionosphere. A convection model originally developed at Rice University was utilized to investigate the electrodynamic coupling between the magnetosphere and thermosphere including the effects of neutral winds, and noting the change in electric fields penetrating to low latitudes due to the wind effects. A unique aspect of the study is that the high-latitude convection-driven winds are included self-consistently and interactively; that is, a steady-state wind parameterization was derived analytically in terms of the electric potential, which is in turn included in a closed-loop calculation for the electric potential itself. An analogous study was performed for the thermosphere-ionosphere system, wherein the</p> <p>(CONTINUED ON OTHER SIDE)</p>			
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19. ABSTRACT (CONTINUED)

balance height of the F-layer was expressed analytically in terms of the meridional neutral wind, and the two parameters allowed to evolve self-consistently within dynamical calculations representing magnetically disturbed and quiet conditions in the thermosphere. In another series of calculations, plasma structures unique to the equatorial ionosphere were modeled analytically and incorporated into a numerical solution of the neutral dynamics to demonstrate the controlling influence of the ionosphere on the equatorial thermosphere. A methodology involving polynomial fitting and color graphics display of global ionosonde data was also developed for analyzing the equatorward penetration of ionosphere-thermosphere coupling signatures during magnetically disturbed periods. The usefulness of this method of analysis is already being realized in research efforts involving global experimental campaigns and their simulation using numerical models, and in the development of operationally useful ionosphere empirical models which include the effects of magnetic storms.

AFOSR-TR- 88 - 1048

Electromechanical Feedback Processes
in the Ionosphere

Final Technical Report

AFOSR Grant 85-0048

1 December 1984 - 31 May 1988

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1. INTRODUCTION

The general goals of AFOSR Grant 85-0048 were to provide a better understanding of observed neutral and plasma structures in the upper atmosphere, and to define appropriate parameterizations for neutral-plasma interactions governing these structures in comprehensive numerical models of the thermosphere and ionosphere. This was accomplished through numerical simulations which address the problems of self-consistently solving for (a) convection electric fields and neutral winds in the polar thermosphere; and (b) plasma density distributions and wind structures in the low and middle latitude thermosphere and ionosphere. All of the accomplishments attained under AFOSR-85-0048 have been made available to the research community through conference presentations and publications. These are listed in the following two sections. Section 4 provides a brief commentary on these results and their contributions to upper atmosphere science.

2. PRESENTATIONS

- (2a). Harel, M. and J.M. Forbes, Quantitative Simulations of the Neutral-Wind/Magnetosphere Interaction, American Geophysical Union Meeting, Baltimore, MD, June 1985.
- (2b). Forbes, J.M. and M. Harel, An experiment in Interactive Modeling: Thermosphere-Magnetosphere Coupling, American Geophysical Union Meeting, San Francisco, CA, December 1985.
- (2c). Harel, M. and J.M. Forbes, Computer Simulations of Ionospheric Electric Fields during the GISMOS Campaign, American Geophysical Union Meeting, San Francisco, CA, December 1985.
- (2d). Forbes, J.M. and R.G. Roble, Experiments in Thermosphere-Ionosphere Interactive Modeling, International Symposium on Large-Scale Processes in the Ionosphere-Thermosphere System, Boulder, CO, December 1986.
- (2e). Forbes, J.M., Codrescu, M. and T.J. Hall, A Methodology for Analyzing the Latitudinal Penetration of Ionospheric Storm Effects using Ionsonde Data, CEDAR Workshop, Boulder, Colorado, June 1987.
- (2f). Batista, I.S., Codrescu, M., J.M. Forbes and D.N. Anderson, Parameterization for hmf2 in terms of Plasma Drifts at Low Latitudes, American Geophysical Union Meeting, San Francisco, California, December 1987.
- (2g). Harel, M. and J.M. Forbes, High-Latitude Neutral Winds and the Equatorward Penetration of Ionospheric Electric Fields, American Geophysical Union Meeting, Baltimore, MD, June 1988.

3. PUBLICATIONS

- (3a). Forbes, J.M., Codrescu, M. and T.J. Hall, On the Utilization of Ionosonde Data for Analyzing the Latitudinal Penetration of Ionospheric Storm Effects, *Geophys. Res. Lett.*, 15, 249-252, 1988.
- (3b). Forbes, J.M., and M. Harel, Magnetosphere-Ionosphere Coupling: An Interactive Experiment, *J. Geophys. Res.*, in press, 1988.
- (3c). Forbes, J.M., Anderson, D.N., Codrescu, M., and Batista, P., An Analytic/Empirical Model of the Middle and Lower-Latitude Ionosphere, AFGL Technical Report, in press, 1988.
- (3d). Anderson, D.N., Forbes, J.M., Codrescu, M., and P. Batista, An Analytic Low and Middle Latitude Ionospheric Model, *Geophys. Res. Lett.*, submitted, 1988.
- (3e). Forbes, J.M., and R.G. Roble, Thermosphere-Ionosphere Coupling: An Interactive Experiment, *J. Geophys. Res.*, submitted, 1988.

4. SUMMARY OF RESEARCH ACCOMPLISHMENTS

Upper atmosphere science is placing increased emphasis on global coupling between the magnetosphere, ionosphere, and thermosphere systems, particularly with regard to the penetration of dynamic, chemical, and electrodynamic effects from high to low latitudes during magnetically disturbed periods. An emerging potential exists for latitudinal and longitudinal chains of ionosondes to contribute uniquely to this thrust in ways complementary to the capabilities and shortcomings of other ground based sensors and satellites. In the Forbes et. al [1988] study, (3a) above, we illustrate a methodology whereby the fullest potential of such ionosonde data can be realized. Data from a chain of stations close to the -165° magnetic meridian and separated by about 5° in magnetic latitude are used to study the relationships between magnetic activity, hmF2, foF2, and inferred meridional winds during 17 - 28 April, 1979. Hourly values are fit in latitude using Legendre polynomials, and variations from quiet-time values are displayed in latitude-U.T. coordinates using a color graphics method which provides an illuminating illustration of the penetration of ionospheric disturbances in latitude and their dependence on Kp, storm time, and local time. Observed effects are interpreted in terms of plausible electric field, neutral wind, and neutral composition changes during the storm period. For instance, net depletions in foF2 occur over the entire disturbed interval down to about 25 degrees to 30 degrees latitude, apparently due to such increased N2 densities that the resulting enhanced plasma loss rates overcompensate any "positive" storm effects whereby southward winds elevate the F-layer peak to altitudes of reduced chemical loss. Positive storm effects are, however, observed at lower latitudes, and may also reflect the influence of electric fields as well as winds. Interestingly, besides reflecting the anticipated southward flows and equatorward extensions in conjunction with magnetically disturbed conditions, the 24-hour average meridional

winds exhibit a northward return flow after the magnetic disturbance has relaxed; this is a new feature of thermosphere dynamics which should be further investigated using general circulation models and other means of inferring the wind field.

In the Forbes and Harel [1988] study, (3b) above, the Rice Convection Model (RCM) is utilized to investigate the electrodynamic coupling between the inner magnetosphere and the thermosphere including the effects of EUV- and convection-driven neutral winds under quasi-equilibrium conditions. It is shown that the parameters determining the coupling are the Pedersen and Hall 'effective winds', which are the height integrals of the respective conductivity-weighted wind profiles divided by the respective layer conductivities. Their appearance in the RCM is equivalent to two-slab formulation whereby the integrated Hall conductivity originates in the upper slab, and the height dependence of the neutral wind is accounted for by assuming different wind vectors for the lower and upper slab. A unique aspect of the study is that the convection-driven winds are included self-consistently and interactively; that is, a steady-state wind parameterization is written analytically in terms of the electrostatic potential, which is in turn included in a closed-loop calculation for the electric potential itself. Simulations are performed from 1400 UT to 1600 UT during the CDAW-6 interval on March 22, 1979, when the cross-cap electric potential attains values of order 140-180 kV. During the early phases of the disturbance when the normal shielding from high latitudes breaks down, the neutral winds do not modify appreciably the disturbance electric fields at middle and low latitudes. As the system approaches a quasi-equilibrium state, the neutral winds play a much more significant role. By comparison with the 'no-wind' simulation, the fields driven by EUV winds counteract the fields of magnetospheric origin and give the appearance of a shielding effect. The convection driven component of the neutral wind similarly acts to reduce the southward field in the noon sector, but gives rise to an enhancement in the dusk sector field extending to middle latitudes. The parameterized Pedersen effective winds are of order 300 m/sec and reflect a two-cell pattern. These amplitudes and similarity with the ion drift motions reflect the relatively large contribution to the Pedersen effective winds originating in the upper E-region and lower F-region of the ionosphere. Possibilities for introducing further sophistication into the wind parameterization are discussed, as well as ramifications of the present study on the possible merging of the RCM with the NCAR TGCN to attain a higher degree of self-consistency and reality in modeling efforts.

The efforts listed under (3c) and (3d) actually represent an outcome of work initiated under the Air Force Reserve activities of the P.I. (Major, USAFR) at the Air Force Geophysics Laboratory, and was only partially supported by AFOSR-85-0048. In this study an improved analytic/empirical model of F-layer plasma density was developed by modifying the Chiu (1975) model so as to (a) better approximate middle latitude F-layer peak heights ($h_m F_2$'s) as derived from ionosonde data, and (b) better model features such as the post-sunset rise in the F-layer peak height, and the "equatorial anomaly" maxima in plasma density near $\pm 15^\circ$ geomagnetic latitude. The latter was accomplished by applying analytic low-latitude corrections derived from differences between the Chiu model and the SLIM model of Anderson et al. (1987a). The extension

of this work involving Boston University resulted from development of a neutral dynamical numerical model under AFOSR-85-0048 for simulating the height-time distributions of neutral winds at any given latitude, subject to specification of horizontal pressure gradients by the MSIS empirical model. This model was used to demonstrate the importance of these low-latitude plasma structures to the neutral dynamics of the thermosphere.

In the Forbes and Roble [1988] effort, the National Center for Atmospheric Research (NCAR) Thermosphere General Circulation Model (TGCM) is utilized to perform a series of controlled experiments aimed at better understanding the interactive coupling between ionospheric plasma densities and thermospheric neutral winds. The experiments are simple and controlled so as to facilitate identification of governing mechanisms. The interaction is accomplished by parameterizing the F-layer peak height (hmF2) in an empirical ionospheric model in terms of the meridional wind v , and forcing hmF2 and v to remain self-consistently coupled in a dynamical calculation. Interactive computations are performed where the TGCM is driven by 30 kV and 90kV cross polar cap potentials, and compared with corresponding reference simulations where hmF2 is held fixed at 280 km. The coupling between hmF2 and v is found to be weak (e.g. self-consistency is not important) during the daytime when the F-layer exhibits a broad vertical structure. At night, when the F2-layer is more localized, the neutral dynamical structure is dependent on whether hmF2 is significantly above or below the altitude (ca. 275-300 km) at which ion drag effectively competes with viscosity in the neutral momentum balance. At Arecibo during both levels of activity, the pre-midnight elevation (+50km) and the post-midnight collapse (-75km) of hmF2 relative to a nighttime balance height of 280 km are accompanied, respectively, by relative increases (15 m/sec) and decreases (42 m/sec) in the zonal wind above 250 km relative to the non-interactive simulation. At Millstone Hill under the 90kV forcing, a 40 km ascension of hmF2 to 330 km around midnight due to southward increase in the zonal wind above 200 km. At both location the meridional wind was found to be considerably less sensitive to plasma density variations for the middle latitude magnetic dip angles pertaining to these simulations.